Powder Metallurgy and Metal Ceramics, Vol. 34, Nos. 1-2, 1995

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SOLIDUS SURFACE AND PHASE EQUILIBRIA DURING THE SOLIDIFICATION OF ALLOYS IN THE Al_2O_3—ZrO_2—Y_2O_3 SYSTEM

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UDC 546-31:621:641:831

The projection of the solidus surface in the Al_2O_3—ZrO_2—Y_2O_3 phase equilibrium diagram was plotted. The scheme of alloy solidification indicates that the primarily congruent modes of phase transformation in the limiting binary systems are retained in the ternary system.

The structure of the limiting binary systems [1-14], phase triangulation [15], liquidus surface [16], and isothermal sections at 1250, 1450, 1600, 1650, and 1800°C [17-20] are known for the Al_2O_3—ZrO_2—Y_2O_3 system. Authors of the isothermal section at 1800°C [18] maintain that all phases of the system are in the solid state at that temperature. However, a ternary eutectic has been found at 1715 ± 20°C [16] including the phases Al_2O_3(A) + F + $Y_3Al_5O_{12}$(Y_3A_5), where F is a ZrO_2-based solid solution with the fluorite structure containing various amounts of Y_2O_3. A proposed variant of the isothermal section [18] should be directed at least to this temperature.

The objective of the present work was to construct a projection of the solidus surface on the concentration triangle, and study the solidification processes in Al_2O_3—ZrO_2—Y_2O_3 alloys.

TABLE 1. Phase Compositions and Initial Melting Temperatures of Specimens in the 50 Al_2O_3·50 ZrO_2—Y_2O_3 Section, Indicating the Location of Phase Fields on the Solidus Surface of the Al_2O_3—ZrO_2—Y_2O_3 Phase Equilibrium Diagram

Composition, mole %			Phase composition	Solidus Temperature, °C
Al_2O_3	ZrO_2	Y_2O_3		
48,5	48,5	3,0	A+T+E	1750
47,5	47,5	5,0	A+T	1745
45,0	45,0	10,0	A+F	1730
42,5	42,5	15,0	A+F+Y_3A_5	1715
40,0	40,0	20,0	The same	1710
37,5	37,5	25,0	" "	1715
35,0	35,0	30,0	Y_3A_5+F	1740
33,5	35,5	33,0	The same	1865
32,5	32,5	35,0	" "	1845
30,0	30,0	40,0	Y_3A_5+F+YA	1840
27,5	27,5	45,0	YA+F	1870
25,0	25,0	50,0	YA+F+Y_2A	1860
22,5	22,5	55,0	The same	1850
21,0	21,0	58,0	Y_2A+F	1940
20,0	20,0	60,0	Y_2A+F+C	1915
17,5	17,5	65,0	The same	1905
15,0	15,0	70,0	" "	1910
12,5	12,5	75,0	Y_2A+C	1915
10,0	10,0	80,0	The same	1925
7,5	7,5	85,0	" "	1925
5,0	5,0	90,0	" "	1935
2,5	2,5	95,0	" "	1950

Institute of Materials Science Problems, Ukrainian Academy of Sciences, Kiev. Translated from Poroshkovaya Metallurgiya, Nos. 1/2(377), pp. 71-76, January-February, 1975. Original article submitted September 13, 1993.

1068-1302/95/0102-0064$12.50

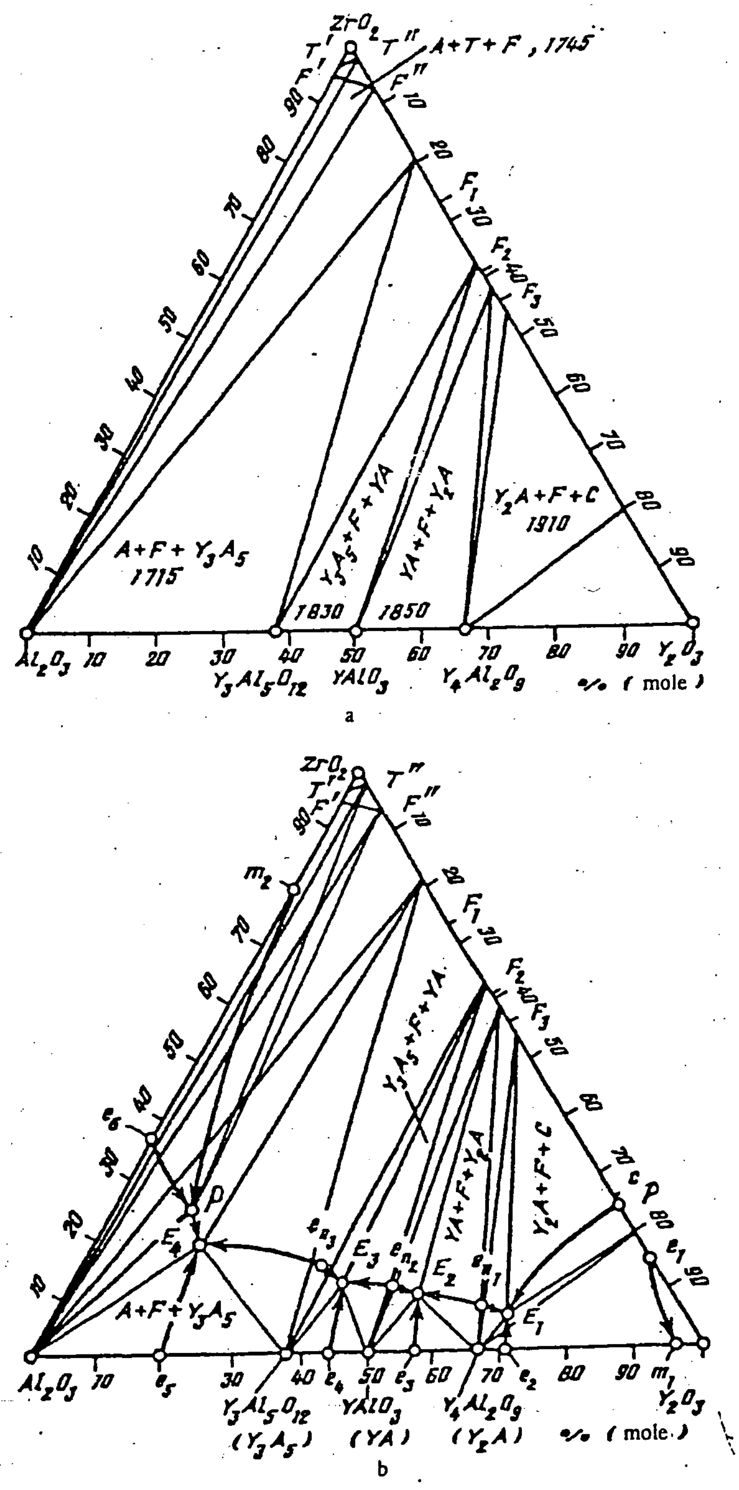

Fig. 1. Projection of the solidus surface (a) and the equilibrium solidification diagram for alloys (b) of the Al_2O_3—ZrO_2—Y_2O_3 system.

TABLE 2. Coordinates of the Apices of the Conodal Triangles for the Solid Phases on the Solidus Surface of the Al_2O_3—ZrO_2—Y_2O_3 System, According to Data Obtained by Microprobe Analysis

Phase field	Compositions of the equilibrium phases, mole %					
	Al_2O_3	Y_3A_5	F	YA	Y_2A	C
A+F+Y_3A_5	0,1/0,06*	0,5/37,4	80,8/19,2			
Y_3A_5+F+YA		1,4/40,5	60,7/39,3	0,80/50,4		
YA+F+Y_2A			59,2/40,8	0,03/50,2	1,0/67,3	
Y_2A+F+C			44,0/56,0		0,3/67,7	19,1/80,9

*The concentration of ZrO_2 is given before, and of Y_2O_3 after the slash.

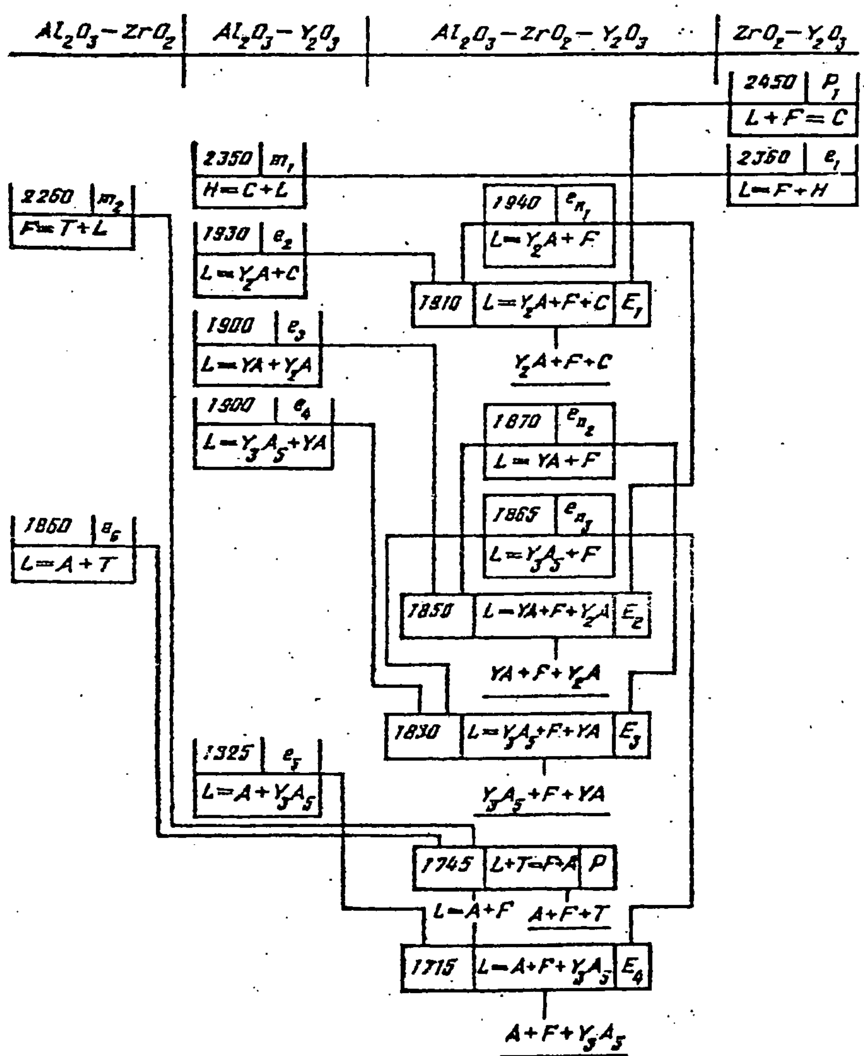

Fig. 2. Reaction scheme for the equilibrium solidification of specimens in the Al_2O_3—ZrO_2—Y_2O_3 system.

The starting materials, and methods of preparing and studying the specimens, are described in [15,16]. Coordinates of the apices of the conodal triangles were determined by microprobe analysis using the "Kamebaks SX-50" unit of the firm "Kameka" (France).

The results of the investigation are shown Fig. 1 in the form of a projection of the solidus surface on the concentration triangle (a), and a solidification diagram (b), for the system. The beginning melting temperatures and phase compositions of alloys in the 50 mole % Al_2O_3·50 mole % ZrO_2—Y_2O_3 section, characterizing the positions of the phase fields on the solidus surface, are given in Table 1.

No ternary compounds or ternary solid solution fields are observed in the Al_2O_3—ZrO_2—Y_2O_3 system. The solidus surface consists of five isothermal three-phase fields corresponding to four invariant equilibria of the eutectic type and one of the peritectic type, ruled surfaces representing the end of solidification of the binary eutectics A + T, A + F, and $Y_4Al_2O_9(Y_2A)$ + C (where T = solid solution based on tetragonal ZrO_2 containing various amounts of Y_2O_3 and C = solid solution based on C-Y_2O_3 containing various amounts of ZrO_2), and the ruled surface F'T'T"F" formed by the sides of the conodal triangles based on the equilibrium phases T and F, whose compositions lie close to the ZrO_2 corner and vary along the curves T'T" and F'F" (Fig. 1a). Data on the coordinates of the conodal triangles are given in Table 2. The microprobe data are confirmed by the results of x-ray diffraction analysis [15].

Between the liquidus and solidus surfaces, the ternary equilibrium diagram contains volumes in which solidification of the binary eutectics A + T, A + F, A + Y_3A_5, Y_3A_5 + F, Y_3A_5 + A, YA + F, YA + Y_2A, Y_2A + F, and Y_2A + C occurs. These are included within the corresponding ruled surfaces and isothermal planes of the invariant transformations.

Figure 2 shows the scheme of reactions for the equilibrium solidification of specimens in the Al_2O_3—ZrO_2—Y_2O_3 system. Equilibrium solidification of the alloys is basically characterized by four invariant transformations at 1910 (E_1), 1850 (E_2), 1830 (E_3), and 1750°C (E_4). A transition from the incongruent three-phase transformation L_p + F = C to the congruent transformation L = F + C occurs along the monovariant curve pE_1. This is terminated by the four-phase invariant transformation L_{E_1} = Y_2A + F + C. A three-phase equilibrium characteristic of a metatectic process F = T + L occurs along the limiting curve m_2P as the temperature decreases from 2260 to 1745°C, and is followed by the four-phase invariant equilibrium L_p + T = F + A at this temperature. The monovariant process L = F + A, which takes place immediately after the peritectic reaction P, occurs with decreasing temperature along the limiting curve PE_4 and is congruent in nature. The point E_4 corresponds to the composition of the liquid which participates in the four-phase invariant equilibrium L_{E_4} = A + F + Y_3F_5 (1715°C). Two additional three-phase congruent processes are terminated at this point: L = A + Y_3A_5, and L = Y_3A_5 + F.

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